QUALIFICATION OF HIGH DENSITY FUEL MANUFACTURING FOR RESEARCH REACTORS AT CNEA (ARGENTINA)

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ABSTRACT

CNEA, the National Atomic Energy Commission of Argentina, is at the present a qualified supplier of uranium oxide fuel for research reactors. A new objective in this field is to develop and qualify the manufacturing of LEU high density fuel for this type of reactors. According with the international trend Silicide fuel and U-xMo fuel are included in our program as the most suitable options.

The facilities to complete the qualification of high density MTR fuels, like the manufacturing plant installations, the reactor, the pool-side fuel examination station and the hot cells are fully operational and equipped to perform all the activities required within the program.

The programs for both type of fuels include similar activities: development and set up of the fuel material manufacturing technology, set up of fuel plate manufacturing, fabrication and irradiation of miniplates, fabrication and irradiation of full scale fuel elements, post-irradiation examination and feedback for manufacturing improvements. For silicide fuels most of these steps have already been completed. For U-xMo fuel the activities also include the development of alternative ways to obtain U-xMo powder, feasibility studies for large scale manufacturing and the economical assessment. Set up of U-xMo fuel plate manufacturing is also well advanced and the fabrication of the first full scale prototype is foreseen during this year.

1. Introduction

CNEA, the National Atomic Energy Commission of Argentina, is a qualified and reliable supplier of uranium oxide fuel for the domestic market and also for the international market [1]. Mainly because of the reduction of enrichment programs, new types of fuels are required by reactor operators. Therefore CNEA's objectives in this field include the development and qualification of LEU high density fuel manufacturing for this type of reactors. According with the international trend Silicide fuel and U-xMo fuel are included in the program as the most suitable options.

This paper briefly describes some of the activities performed within these programs and provides results obtained during their different steps.

2. High density fuels

When the U_3O_8 fuels development and set up at industrial scale was completed CNEA activities were focused in the development of high density U_3Si_2 fuel with a density of 4.8 gU/cm^3 and the improvement of the manufacturing process to obtain the U_3Si_2 powder. More recently and according with the international trend in this field, CNEA started also with the development of a new type of fuels bearing very high density fuel materials (U-xMo) and a density up to 7 gU/cm^3.

Qualification programs of similar characteristics were established for both type of fuels. These programs are described in the following points.

3. Description of the Qualification Programs

The programs for both type of fuels include the following activities: development and set up of the fissile compound manufacturing technology, set up of fuel plate manufacturing, fabrication and irradiation of miniplates, fabrication of fuel assembly prototypes for irradiation, post-irradiation examination and feedback for manufacturing improvements. For silicide fuels most of these steps has already been completed. For U-xMo the fabrication of the first full scale prototype is foreseen during 2001.

4. CNEA's Facilities

The facilities required for the qualification of high density MTR fuels, like the manufacturing plant, the pool-side fuel examination station and the hot cells were lengthy described in [2]. This facilities are fully operational and equipped to perform all the activities needed to complete the programs.

As was previously reported [3], the fabrication facilities were improved and upgraded to set up the equipment necessary for silicide material fabrication. The RA-3 reactor is being upgraded to 10 MW and the hot cells are also operating. These hot cells have been already used for the non-destructive examinations of P-04, the first silicide fuel element manufactured and irradiated in Argentina.

5. Status of the silicide fuel qualification

As was mentioned, most of the steps related with the qualification of silicide fuel has been already completed. PIE of the first full scale demonstration fuel element (P-04) is almost finished. One FE (P-06) is being irradiated in the RA-3 and another one will be loaded in April. Figure 1 shows a simplified schedule of the operational stage of this program.

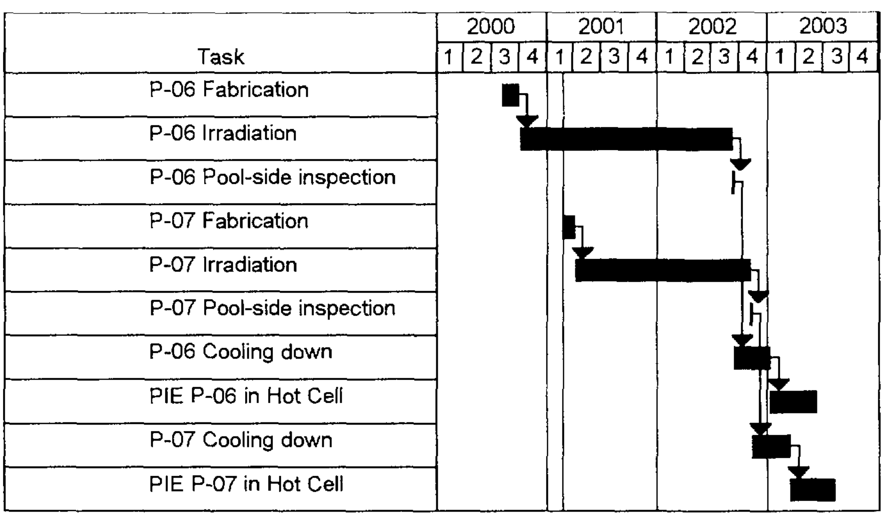

Figure 1: Simplified Schedule of the Silicide Fuel Manufacturing Qualification

5.1 Considerations about using U_3Si_2 and its manufacturing process

The use of U_3Si_2 in research reactors has been widely evaluated and demonstrated within the framework of the RERTR program. The aspects associated to the use of U_3Si_2 as fuel material were analyzed and evaluated by the US Nuclear Regulatory Commission, the results of such evaluation was included in the NUREG-1313 report [4].

The U_3Si_2 used in our qualification program is fully manufactured in CNEA fulfilling NUREG-1313 recommendations. Its development and results were reported in [5].

5.2 Main characteristics of U_3Si_2

The total uranium and silicon contents of the U_3Si_2 ingots are checked and a metallographic control is also carried out. Typical contents of U and Si are 91,76 % and 7,53 % respectively.

Once the grinding process is completed, the material is sifted and adequately mixed to obtain, as shown in Figure 2, a powder with a maximum particle size below 100 μm and with under 50 % of particles below 45 μm. The density of the resulting powder ranges from 12 to 12.1 g/cm3.

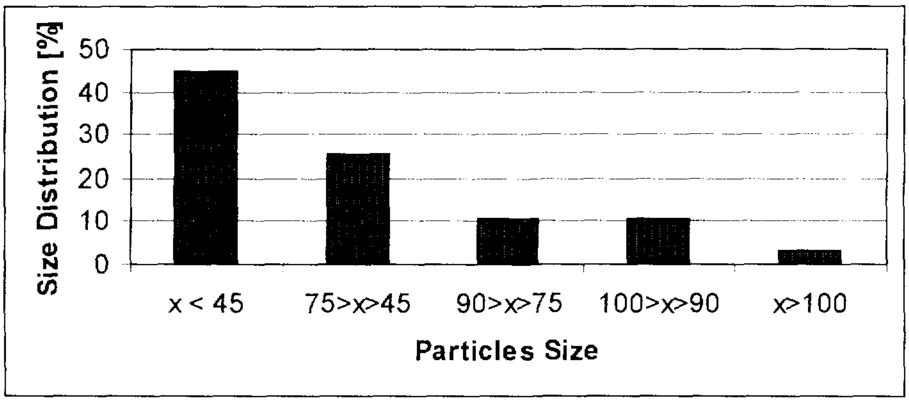

Figure 2: Particle size distribution for U_3Si_2 powder production

The content of impurities is well controlled and the typical uranium plus silicon content in the powder is above 99.3 weight %.

5.3 Fuel Plate manufacturing

The fuel plate manufacturing has been set up. Figure 3 shows a typical distribution of plate thickness along a fuel plate, at 9 different positions

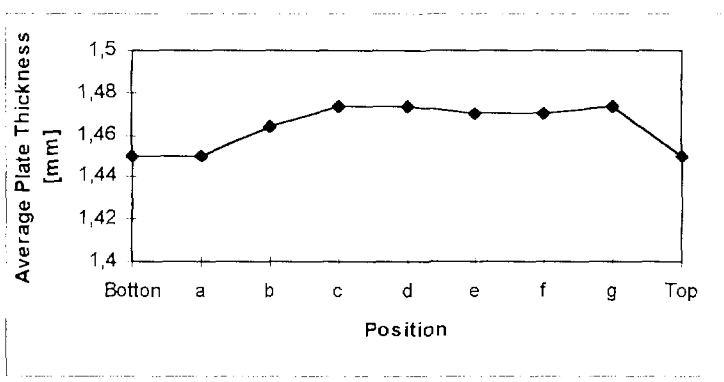

Figure 3: Typical distribution of plate thickness along a fuel plate

At the present the set up of the manufacturing of thinner plates (1,3 mm) is completed and the results are being evaluated.

5.4 Full Scale Fuel Element Irradiation

The qualification program of silicide fuels includes the irradiation of two full scale fuel elements. The following Table shows a comparison of the main parameters of both fuel elements P-06 and P-07

Fuel Element				P-06	P-07
Fuel				U_3Si_2 - Al	
Fuel Plates				19	20
Meat dimensions	Length		[mm]	619	615
	Width		[mm]	60	
	Thickness	Outer	[mm]	0,51	0,61
		Inner			
Fuel Plate dimensions	Length	Outer	[mm]	735	735
		Inner		655	665
	Width	Outer	[mm]	70,8	70,5
		Inner			
	Thickness	Outer	[mm]	1,5	1,5
		Inner			1,35
Cladding Thickness		Outer	[mm]	0,495	0,45
		Inner			0,37
U_3Si_2-Al Density			[g/cm3]	6,54	6,54
Enrichment U^{235}				19,78 ± 0,012 % U weight	
U_{total} Density			[g/cm3]	4,8	
Gap between fuel plates			mm	2,7	2,6

The first pool-side inspection of P-06 after 3 month of irradiation was completed; no undesirable or unusual findings were reported. Figure 4 shows a picture of the element with backlighting during the inspection.

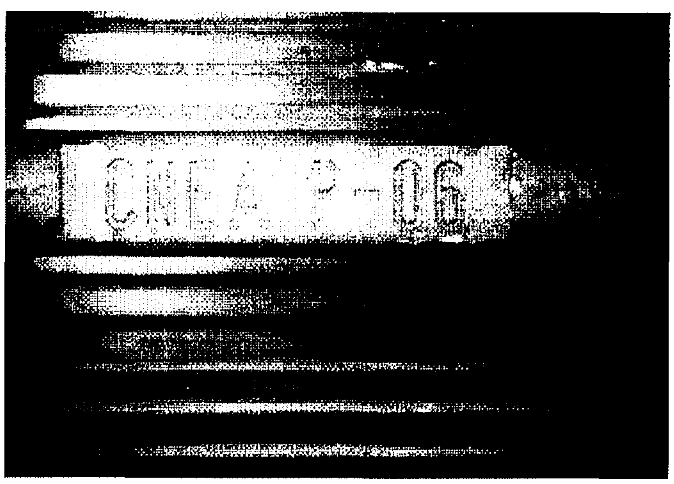

Figure 4: Picture of element P-06 during the pool-side inspection

6. Status of U-Mo fuel qualification

Another objective of CNEA is to develop and qualify the technology for the production of high-density LEU fuel elements using U-xMo alloy.

6.1 Alternative manufacturing routes

One of the main activities related with this program is the development of alternative U-Mo fabrication routes. The most suitable options at the present are: Conventional Atomization, Cyclonic Centrifugal Atomization (CCA) and the hydriding and dehydriding technique. Initial results using this process were reported in [6]. The activities related with the alternative routes will include full testing and irradiation with U-Mo powder coming from different routes and finally the development of powder specifications. The main characteristics under analysis are the shape and size distribution of the U-Mo particles and the content of impurities.

6.2 Setup of Fuel Plate Manufacturing and Irradiations

Currently the main activity within this program is the adjustment of fuel plates manufacturing using natural U-7Mo powder supplied by KAERI and prepared by the centrifugal atomization process. Several fuel plates have been manufactured. The influence of filling technique and tooling has been analyzed. Uranium density is 7 gU/cm^3. Porosity within the plates is close to 5 %. The process is now under further improvements and refinements. Quality control techniques are also being set up for this material and the fuel plate fabrication is expected to be consolidated before the end of this year.

6.3 Irradiation

The next step will be the fabrication and irradiation of full-size fuel elements. To fulfil this objective fuel plates will be fabricated using LEU U-7Mo also from KAERI. At the present it is planned to build three full-sized fuel elements for irradiation in the RA-3 reactor. The target burnup will be 50-70 % and the irradiation of the first of these fuel elements is expected to start by the end of 2001.

7. Conclusions

CNEA has built a wide experience on designing, development, qualification and fabrication of MTR fuel elements. In the high density fuels area, U_3Si_2 qualification is well advanced and U-Mo development and qualification is in progress. The development and qualification of these technologies associated with the fabrication and irradiation of U_3Si_2 and U-xMo fuels in Argentine research reactors will allow CNEA to fulfill satisfactorily the new requirements of potential customers.

8. References

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